

them. These include, for instance, the super-determinism approach of the theoretician Gerard 't Hooft.

The book is, however, upbeat and, finally, optimistic. Unapologetically drawing on historical tradition and even modern philosophy, Smolin proposes a new set of principles that applies to both quantum mechanics and space-time. He then explores how these principles might be realized as part of a fundamental theory of nature, although he stops short of supplying details of the implementation.

Smolin concludes with the implications of all this for our understanding of space and time. He suggests that time is irreversible and fundamental, in the sense that the processes by which future events are produced from present ones are truly basic: they do not need to be explained in terms of more basic ideas. Space, however, is different. He argues that it emerges from something deeper.

Yet it is far from clear whether Smolin's new methods allow space and time to be investigated effectively. In recent decades, there have been many exciting advances in this subject, almost all made using standard quantum mechanics and Einstein's theory of relativity. In my opinion, Smolin downplays the extraordinary success of this conservative approach. It is the basis of modern quantum field theory (a descendant of Maxwell's theory of electricity and magnetism), which accounts for the results of all subatomic experiments, some of them to umpteen decimal places. Despite the impression that Smolin gives, modern theoretical physics is thriving, with potentially revolutionary ideas about space and time emerging from a combination of the standard quantum mechanics and relativity theory taught in universities for generations. Maybe the upheaval in physics that Smolin yearns for is simply unnecessary.

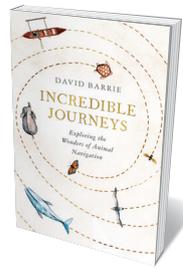
Rewarding as it is, I doubt *Einstein's Unfinished Revolution* will convert many of Smolin's critics. To do that, he will need to present his ideas more rigorously than he could reasonably do in a popular book.

One thing on which every physicist in Smolin's field can agree is that there is a crying need for more juicy clues from nature. There have been no surprises concerning the inner workings of atoms for some 20 years. It is experimental results that will decide whether Smolin is correct, or whether he protests too much. After all, although quantum mechanics might not satisfy the philosophically minded, it has proved to be a completely dependable tool for physicists — even those who have no interest in debates about its interpretation. ■

Graham Farmelo is a fellow of Churchill College at the University of Cambridge, UK. His latest book is *The Universe Speaks in Numbers*.

e-mail: g.farmelo@virginmedia.com

Books in brief



Incredible Journeys

David Barrie HODDER AND STOUGHTON (2019)

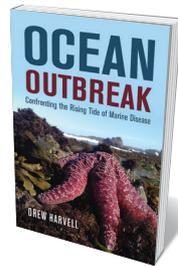
How does the blind Mexican cave fish (*Astyanax mexicanus*) navigate convoluted pools, or the tiny blackpoll warbler (*Setophaga striata*) fly non-stop for 2,770 kilometres over open ocean? In this exhilarating popular study, David Barrie reveals the roots of navigational prowess — such as the adapted eye and biological clock of the desert ant *Cataglyphis*, which function as a compass oriented to the Sun, or the myriad species that use olfaction, Earth's magnetism, sonar or cognitive mapping to find their way. The navigational nous of humans from astronauts to Indigenous peoples gets a look-in, too.



Vanishing Ice

Vivien Gornitz COLUMBIA UNIVERSITY PRESS (2019)

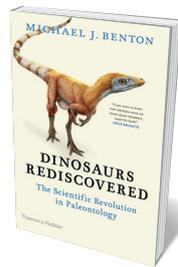
Whether it's shrinking ice shelves in Antarctica or Greenland's destabilizing ice sheet, the cryosphere is in flux, and this solid scientific primer by geologist Vivien Gornitz examines the human costs. In the context of deep time, she explores dwindling glaciers, thawing permafrost and other shifts that are leading to buckled land, diminished water supplies, serious sea-level rise and other impacts that, together with fiercer hurricanes, pose an existential threat that must be fought with decarbonization and innovative adaptation. A cogent analysis of this systemic, human-driven catastrophe.



Ocean Outbreak

Drew Harvell UNIVERSITY OF CALIFORNIA PRESS (2019)

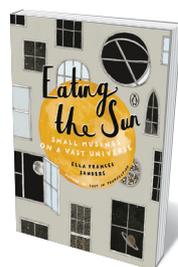
Abalone, corals, salmon and starfish: populations of these four marine animals are under siege from disease. The culprit, notes ecologist Drew Harvell in her succinct summation of two decades of research, is us — specifically, a confluence of ocean warming and acidification, dredging, oil extraction, overfishing and pollution. Harvell vividly recounts her work at the front line, studying die-offs such as the past decade's catastrophic starfish crash. Yet she is hopeful, noting that policy change, with techniques such as plant biofiltration and phage therapy, could still turn this malign tide.



The Dinosaurs Rediscovered

Michael J. Benton THAMES & HUDSON (2019)

Palaeobiology is a field on fire with discoveries, such as China's panoply of feathered dinosaurs and the titanic sauropod fossils recently excavated in Patagonia. With advances in technology, that upheaval has transformed the discipline from natural history to testable science. In this illustrated update of dinosaur behaviour, cognition and locomotion, palaeontologist Michael Benton shows how technologies such as scanning electron microscopy reveal feather colour; 3D computer models indicate bone properties; and computation helps to build (and fell) evolutionary 'trees'.



Eating the Sun

Ella Frances Sanders PENGUIN (2019)

With this pairing of witty illustrations and an open-weave narrative — strong on science but just this side of poetry — Ella Frances Sanders has penned a pocket-sized book vast in ambition. She distils phenomena, laws and principles, from heat, light and Earth's gravitational pull on the Moon to *Eigengrau*, the greyness seen in perfect darkness. You find yourself constantly reframed (say, as stardust, the "remnants of burning giants"), and see the Universe unpeeled to reveal the dance steps of electrons, the three hearts of a squid or the joys of noctilucent clouds. [Barbara Kiser](#)